DRAIN SPACING EFFECTS ON WATER TABLE CONTROL AND CANE SUGAR YIELDS

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ABSTRACT. *An experiment was conducted in Southern Louisiana during 1980 through 1990 to determine soil and crop response to subsurface drainage. Three subsurface drain spacings, 14, 28, and 42 m, were tested on Jeanerette silty clay loam soil. The 14 and 28 m spacings were most effective in controlling the water table: average annual SEW_{30} values were 46 and 122 cm-d, respectively. Average annual SEW_{30} value for the 42 m spacing was 242 cm-d while that from the nondrained check was 642 cm-d. Sugarcane responded favorably to subsurface drainage. Average annual sugar yields were 6041 kg/ha from the 14 m spacing, 6029 kg/ha from the 28 m spacing, 5788 kg/ha from the 42 m spacing, and 4990 kg/ha from the check. Yields among the three drained treatments were not significantly different, but yields from the drained treatments were significantly greater than those from the nondrained check. The value of the average sugar yield increases from both the 28 m and the 42 m spacings more than justified the cost of installing subsurface drainage systems. The drainage costs included 10% interest and a 10-year amortization period. Since there was no statistically significant crop yield advantage to subsurface drains spaced closer than 42 m, the drain spacing recommended for draining Jeanerette silty clay loam soil in Louisiana is 42 m.* ***Keywords.*** *Drainage, Water table, Subsurface drainage, Drainage intensity, Drain spacing, Pumped drainage, Drainage cost, Drainage economics, Sugar yield.*

Subsurface drainage is used for crop production in various parts of the United States. In the west, it is used to intercept rising saline water tables before they reach the crop's root zone. In the midwest and northeast, it is commonly used to alleviate excess water problems by aerating the soil and enhancing trafficability at crop planting and harvesting times. In the southeast, particularly in the South Atlantic States, farmers are beginning to use subsurface drains for both drainage and subirrigation. Excess water is drained from the soil profile during wet, rainy, periods and the same system is used to add water to the soil profile during droughts.

In the lower Mississippi Valley (Louisiana, Mississippi, and Arkansas) subsurface drainage has not yet become a common practice. Drainage ditches are used to remove runoff from fields but no special effort is made for improving soil profile drainage although the ditches do provide some benefit. The absence of an intensive drainage system to remove excess water from the soil profile may be one of the reasons crop yields in the lower Mississippi Valley (LMV) are, in general, below the national average. Conditions exist in the valley which indicate the need for soil profile drainage. For example, the major farming areas are at low elevation and adjacent to large bodies of water. High rainfall, varying from 1000 to 2000 mm annually, keeps the water table near the soil surface.

For many years, a misconception existed that hydraulic conductivities of many soils in the LMV were so low that the soils would not respond to subsurface drainage. A basis for this misconception was provided by publications reporting soil physical characteristics which indicated very low hydraulic conductivity values for these soils (Lund and Loftin, 1960; Lund et al., 1961). Experiments conducted in Baton Rouge, Louisiana, beginning in the mid 1960s, demonstrated that silt loam soils responded favorably to subsurface drainage (Carter et al., 1983). They used 40-m^2 concrete-bordered field plots to show that the water table in Mhoon silt loam soil could be maintained readily at 0.3, 0.6, 0.75, 1.0, or 1.2 m. Furthermore, sugarcane, a major crop grown in Louisiana, responded favorably to subsurface drainage and water table control (Camp and Carter, 1983).

Since the experiments in the 1960s and 1970s were conducted on small plots with subsurface drain spacing of only 2.75 m, there was a need to determine soil and crop responses to subsurface drainage on field-size areas. Furthermore, there was a need to determine soil and crop response to various subsurface drain spacings since there were no developed guidelines. Thus, the objectives of this experiment were to:

- Determine the response of Jeanerette silty clay loam soil to three subsurface drain spacings.
- Determine sugarcane response to three subsurface drain spacings.
- Determine if the cost of subsurface drainage could be justified by the increase in crop yield.

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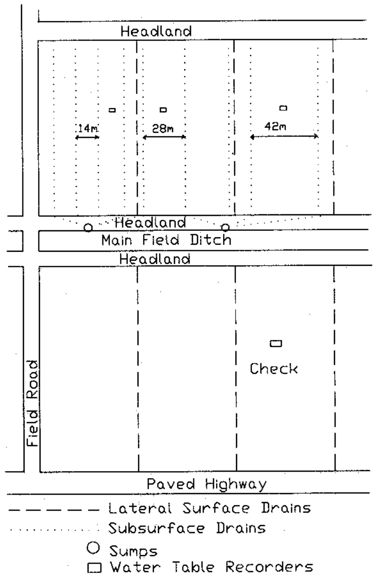

Figure 1–Field layout for subsurface drain spacing experiment in Iberia Parish, La.

PROCEDURE

A Jeanerette (Typic Argiaquoll) silty clay loam site at the William Patout, III farm in Iberia Parish, Louisiana, was selected for this subsurface drainage experiment. Four tracts, each approximately 1.5 ha in size, were used (fig. 1). Subsurface drains were installed on three tracts in 1978. One tract, not subsurface drained, was used as a check. The perforated, corrugated, polyethylene subsurface drains were 102 mm in diameter and were wrapped with Typar filter material. The drains were installed approximately 1.0 m deep with a drain-tube plow equipped with a laser grade control system. In one tract, four drains were installed and spaced 14 m apart. In the next tract, three drains were installed and spaced 28 m apart. In the third tract, two drains were installed and spaced 42 m apart. The drains were connected to two sumps that were equipped with pumps, which discharged drain effluent into a surface drainage ditch. The nondrained tract was across a drainage ditch from the 42-m drain spacing treatment (fig. 1). Each tract was bordered on the sides by surface drainage ditches approximately 0.6 m deep and on the lower end by a surface drainage ditch approximately 1.0 m deep (fig. 1). The tracts were bordered on the upslope ends by field roads.

All tracts were planted to sugarcane in the fall of 1979. Conventional cultural practices were used throughout the experiment, which included planting on 30-cm-high beds with rows spaced 1.8 m apart. Fertilizer and pesticides were applied at rates recommended by the Louisiana Cooperative Agricultural Extension Service.

At harvest time, a whole-stalk mechanical harvester was used to cut, top, and place the cane stalks in either three- or four-row heaps after which the leaves remaining on the stalks were burned. Sugarcane stalks from four sites (each approximately 0.12 ha in size) in each tract were transported to the factory, weighed for yield estimates, and tested for sucrose content. Sugar yield was determined from cane weight and sucrose content. Yields were compared among treatments to determine crop response to drainage and to drain spacings.

Normally, three sugarcane crops are usually harvested from one planting in Louisiana, therefore, a new crop was planted three times during this experimental period. Cane was planted in the fall of 1979, 1983, and 1988. Three crops were harvested from the first planting, four crops from the second planting, and only two crops from the third planting. Below-freezing temperatures in December 1989 severely damaged the cane stubble of the 1988 planting, resulting in severely reduced 1990 crop yields. Consequently, the landowner chose to destroy the stubble and replant in the fall of 1991. Since the objectives of this experiment had been met, the project was terminated after crop harvest in 1990.

Rainfall was measured with a weighing-type rain gauge located at the site. The water table was measured with water stage recorders, one recorder in each tract. In the drained areas, water stage recorders were located midway between two parallel subsurface drains. In the check area, the recorder was located near the middle of the tract. Each recorder was positioned over a 1.8-m-long, 20-cm-diameter PVC pipe that was inserted vertically in a 1.5-m-deep hole augered into the soil. The deeper 1.2-m section of the pipe was perforated so that water could readily flow through the PVC well casing. The well casing extended 0.3 m above the soil surface. The soil surface was sloped away from the well casing to prevent surface water from entering the wells. Recorder stands were positioned over the pipe so the recorder's float and counterweight remained within the PVC pipe. The recorders were installed in 1979 and remained in place throughout the experiment except for periods in November and December each year when they were removed for harvest and during 1983 and 1988 when the land was fallow prior to planting. Water table data from recorder charts were mechanically digitized and stored in computer files. These data were used for evaluation and for calculating SEW_{30} as described by Sieben (1964) as cited by Wesseling (1974). SEW_{30} is the summation of daily occurrences of excess water within 30 cm of the soil surface and may be expressed as:

$$SEW_{30} = \sum_{i=1}^{n} (30 - x_i)$$

where

SEW_{30} = summation of the water table within 30 cm of the soil surface in cm-d

x = water table depth in centimeters on day i

n = number of days to be considered

The SEW_{30} values from the four tracts were compared to determine the effects of drain spacings. To determine whether the cost of subsurface drain installation could be justified by the value of sugar yield increases, drain installation costs were estimated. The material costs, based on 1993 prices and quoted by a plastic drain tubing company representative, were \$0.95/m for 102 mm perforated plastic drain tubes with filter fabric, \$4.80 each for tee adapters, \$0.70 each for drain tube couplers, \$0.80 each for end caps, and \$1.48/m for 152-mm-diameter main drain tubing. The estimated cost for a sump and pump for drainage outlet was estimated at $247/ha. Metal sumps 1.2 m × 1.2 m × 3 m in size and equipped with 0.5 hp sump-pumps were used; they have been adequate for discharging drain outflow into surface drainage ditches at other locations in south Louisiana. Because no subsurface drainage contractors are currently located in Louisiana, the drain line installation cost estimate was based on the average cost for several drain installations in the midwestern area of United States ($0.918/m). Market price for raw sugar in 1993 was $0.485/kg, but farmers received only $0.29/kg because the sugar mill operator charged 40% of the market price to process the cane into sugar.

Because of the size and nature of this experiment, it was difficult to replicate the drain spacing treatments. However, nine years of yield data were collected from four drainage variables (three drain spacings and one nondrained check). These data were tested statistically for normality, interactions, differences, and trends using univariate analysis, plotting programs, and ANOVA methods available from the Experimental Statistics Department at Louisiana State University.

Table 1. Annual rainfall and SEW_{30} for three subsurface drain spacings and no subsurface drainage in Iberia Parish, La.

		SEW_{30}			
		Spacing			Non-drained
Year	Annual Rainfall	14 m	28 m	42 m	Check
	(mm)	(cm-d)			
1980	1689	429	440	742	915
1981	1169	0	39	83	519
1982	1834	0	86	311	975
1983	1644	--	--	--	--
1984	1306	91	106	132	872
1985	1553	22	123	196	658
1986	1288	0	18	44	114
1987	1463	106	303	676	1068
1988	1523	--	--	--	--
1989	1464	0	0	0	83
1990	1092	0	0	0	630
Avg.	1457	72a*	124b	242c	648d

* Average SEW_{30} values followed by the same letter are not significantly different at the 5% significance level.

Results and Discussion

Rainfall during this experiment was erratic, both in amount and distribution. Average annual rainfall during 1980 through 1990 was 1457 mm, which was slightly less than the long-term average of 1500 mm for Iberia Parish. Annual rainfall varied from 1092 mm in 1990 to 1834 mm in 1982 (table 1). Monthly rainfall varied from 15 mm in February 1981 to 478 mm in October 1984.

Rainfall raised the water table to near the soil surface on many occasions. In the nondrained tract, the water table remained near the soil surface for several days following rainfall while the water table in the drained tracts receded to a depth of 0.3 m and more, soon after rainfall (fig. 2). SEW_{30} values for each tract reflected the water table presence within the top 30 cm of the soil (table 1). Annual SEW_{30} values varied considerably, but SEW_{30} values were less for the 14-m-spaced drains and increased as distance between drains increased in all cases. The greatest SEW_{30} values occurred in the nondrained check tract.

Differences in SEW_{30} values among treatments indicated the favorable response of Jeanerette silty clay loam soil to subsurface drainage. Average annual SEW_{30}

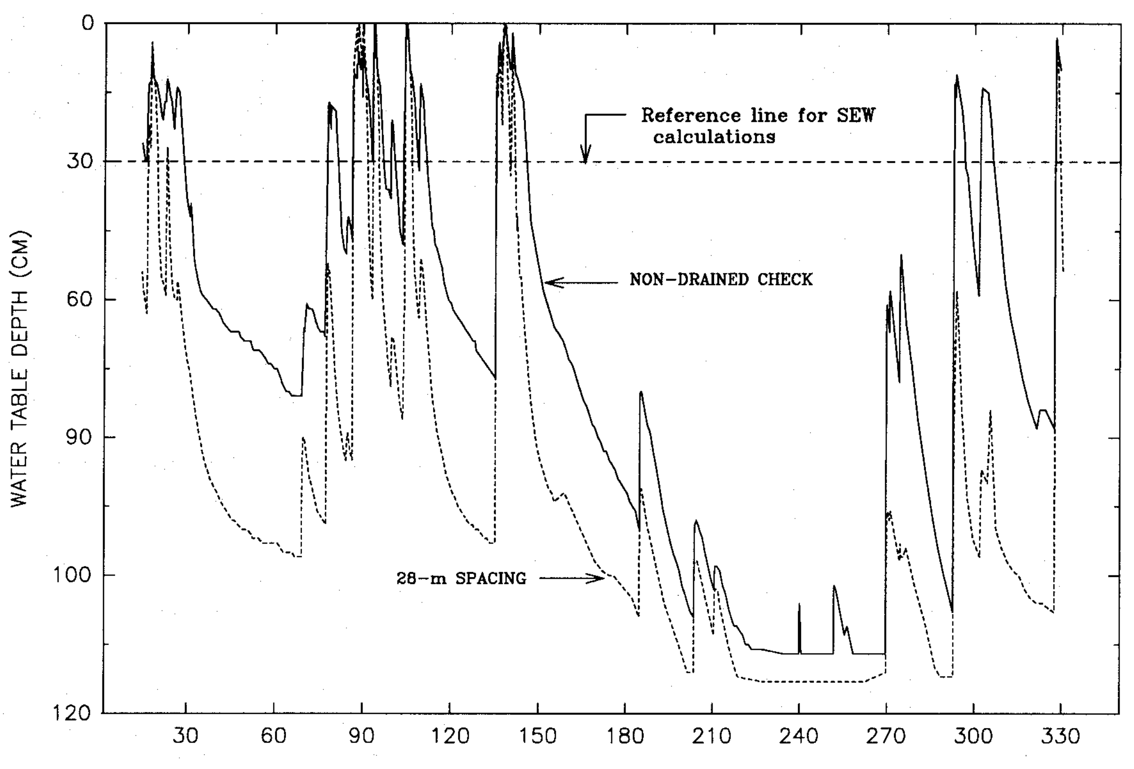

Figure 2–Water table depths for areas with and without subsurface drainage on Jeanerette silty clay loam soil in 1980.

values from the subsurface drained tracts were at least 63% less than values for the nondrained check (table 1). Drains spaced 42 m apart reduced average annual SEW_{30} values 63% (from 648 cm-d to 242 cm-d). Drains spaced 28 m apart reduced average annual SEW_{30} values 81% (from 648 cm-d to 124 cm-d). Drains spaced 14 m apart reduced average annual SEW_{30} values 89% (from 648 cm-d to 72 cm-d).

Sugarcane crop production requires a large amount of water, but, excess water can reduce yields. Sugar yields varied considerably during this study (table 2) with the greatest yields being produced in 1989 and the least yields being produced in 1990. Yields from the 14- and 28-m drain spacings were similar most years. During the first crop cycle (1980 to 1982), yields from the 42 m spacing were consistently greater than those from the nondrained area but less than yields from the 14- and 28-m drain spacings. During the second crop cycle (1984 to 1987), yields varied among treatments with the check area yielding slightly more than drained treatments some years. In general, differences in yield among treatments were small during the second crop cycle. During the third crop cycle (1989 to 1990), yields among the three drain spacings were similar, but they were considerably greater than those from the nondrained check (table 2). The highest sugar yields during the entire experiment were produced in 1989. These high yields were attributed to unusually high sugar content of the cane juice that year rather than to high biomass production. The high sugar content is attributed to favorable weather (dry and cool conditions) and low water table during the cane ripening period in 1989.

A severe freeze occurred in December 1989 after harvest. This was followed with above average rainfall in the early part of 1990. Because sugarcane is reproduced vegetatively from either seed pieces or stubble, the combination of the freeze and wet soil from the winter rains destroyed a large portion of the sugarcane crop for 1990. Sugarcane in the nondrained area of this experiment was damaged severely, consequently sugar yields from this treatment were very low in 1990, only 1480 kg/ha (table 2). Sugar yields from the subsurface-drained tracts were below normal for first-stubble yields, but were much greater than those from the nondrained check. The yield differences between drained and nondrained treatments in 1990 are attributed to improved drainage during the wet periods following the freeze rather than by any effect during the freeze.

Table 2. Sugar yields for three drain spacings and a nondrained area in Iberia Parish, La., during an 11-year period

	Sugar Yield			
	Drain Spacing			
	14 m	28 m	42 m	Nondrained
Year	(kg/ha)			
1980	5893	5915	5671	5166
1981	7968	7974	7505	6003
1982	5399	5577	3941	3116
1983	----	----	----	----
1984	5417	5809	6287	5765
1985	6398	6780	5750	5944
1986	5895	5451	5790	5742
1987	5454	4657	5306	5288
1988	---	----	----	----
1989	8412	8069	8185	6409
1990	3535	4031	3660	1480
Avg.	6041a*	6029a	5788a	4990b

* Average yields followed by the same letter are not significantly different at the 5% significance level.

Yield differences between the drained and nondrained treatments from all nine crops in this study (11 years) were compared to determine the crop response to subsurface drain spacings. Sugar yields from the 14- and 28-m drain spacings were similar (6041 kg/ha and 6029 kg/ha) and were 21% greater than the nondrained yield (table 2). The 42-m drain spacing yielded 5788 kg/ha, 16% greater than the nondrained yield and 4% less than 14 and 28 m spacings. Statistical analyses indicated that yields among the subsurface drained treatments were not significantly different at the 5% significance level. However, sugar yields from the drained tracts were greater than those from nondrained areas and the difference was highly significant. Because the 1990 sugar yield data were from a ratoon crop following a severe freeze, we were concerned that the 1990 data might bias the statistical analysis in favor of the drained treatments. Thus, the data were tested again for significance, but with the 1990 data omitted. The revised statistical analysis indicated the same significant differences as the original analysis.

Although the threshold SEW_{30} value to cause significant sugarcane yield decrease is not known, data from this experiment indicated that, on the average, it is greater than 242 cm-d annually (tables 1 and 2). Unlike most crops that have 75- to 120-day growing season, the sugarcane growing season in Louisiana is approximately 270 days (9 months). Furthermore, two ratoon crops are normally grown following the first crop produced from planted seed pieces; consequently, the stubble remains in the soil continuously during the normal three-year crop cycle. Because of this, annual SEW_{30} values, rather than 270-day SEW_{30} values (growing season only), must be considered in determining the threshold SEW_{30} values to prevent decline of sugar yield. Also, particular emphasis should be placed on SEW_{30} values during the time when sugarcane is most susceptible to high water tables, such as during the dormant-to-early-growth and the grand-period-of-growth stages (Gayle et al., 1987).

The increase in sugar yields attributed to subsurface drainage, observed in this experiment, may encourage farmers in the LMV to consider installing subsurface drainage if the installation cost can be justified. Subsurface drainage installation costs are summarize in table 3. To

Table 3. Subsurface drainage installation costs

		Costs				
Drain Spacing (m)	Drain Length (m/ha)	Drain ($/ha)	Main and Fittings* ($/ha)	Drain Install ($/ha)	Drain Outlet† ($/ha)	Total ($/ha)
14	714	678	96	657	247	1678
28	357	339	89	328	247	1003
42	238	226	84	219	247	776

* Includes cost of the 152-mm-diameter main drain, all couplings, adapters, tees, end plugs, and the installation cost of the main drain.

† Includes the cost of a 1.2 m × 1.2 m × 3 m metal sump and a 0.5 hp electric pump with float control switches.

determine whether subsurface drainage can be justified, only the value of crop yield increases due to subsurface drainage was considered—the value of improved cropping efficiency and improved machinery trafficability were not included in the analysis although they were recognized as benefits.

Average increases in sugar yield attributed to improved drainage were 1051 kg/ha from the 14 m spacing, 1039 kg/ha from the 28 m spacing, and 798 kg/ha from the 42-m drain spacing (table 2). Using 1993 prices, the value of these yield increases were $305/ha, $301/ha, and $231/ha, from the 14-, 28-, and 42-m drain spacings, respectively. A farmer who decides to install subsurface drainage for sugar production may pay cash for drain installation. This installation cost may be repaid within a few years by the value of the increase in sugar yield. Thereafter, a return on the investment is achieved as sugar yield increases continue beyond the pay-back period and for as long as the subsurface drains function properly. The number of crops (average yields) required to offset installation costs for subsurface drainage systems, before a return on the investment can be achieved, is six for the 14 m spacing, and four for the 28 and 42 m spacings.

An alternative approach to dealing with drain installation costs is to borrow funds to pay the initial cost and use the increase in sugar yields, due to subsurface drainage, to repay the loan. In this approach, the amortization period will probably be limited to 10 years (lending institution will decide this) instead of the life of the drainage system, which is more than 20 years. Assuming that interest rates are 10% and the amortization period is 10 years, the cost of installing drainage systems used in this experiment is $2,660/ha, $1,590/ha, and $1,230/ha for the 14, 28, and 42 m spacings, respectively (table 4). Since eight sugar crops are normally grown in a 10-year period in Louisiana, the needed yield increase in eight sugar crops must be sufficient to make 10 payments before the cost of installing drains is justified. The needed yield increase was exceeded by the 28- and 42-m drain spacing treatments, but not by the 14-m spacing treatment (table 4). Thus, the cost of installing subsurface drainage was justified by the value of the increase in sugar yields for drains spaced 28 and 42 m, but not for drains spaced 14 m.

The statistical analysis showed no significant difference in yields among the three drain spacing treatments. This means that, from a statistical standpoint, there was no significant yield advantage to drain spacings closer than 42 m. Thus, 42 m is the recommended drain spacing for Jeanerette silty clay loam soil unless the trafficability benefit of closer spacing is desired, then the 28-m drain spacing is recommended. The cost of installing drainage systems with drain spacings of 42 and 28 m was readily justified by increased sugar yields (table 4).

Table 4. Sugar yield increases needed to justify the cost of installing subsurface drainage in silty clay loam soil

Drain Spacing (m)	Drain Install Cost ($/ha)	Interest Cost* ($/ha)	Total Cost ($/ha)	Annual Payment ($/yr)	Yield Increase Needed† (kg/ha)	Yield Increase Observed ($/ha)
14	1678	982	2660	266	1147	1051
28	1003	587	1590	159	685	1039
42	776	454	1230	123	530	798

* Based on 10% interest and 10-year amortization period.

† Eight sugar crops are normally grown in a 10-year period in Louisiana. Thus, the needed yield increase in eight sugar crops must be sufficient to make 10 payments to justify the cost of installing drains.

Summary

Three subsurface drain spacings were evaluated on Jeanerette silty clay loam soil planted to sugarcane. The SEW_{30} values were used to determine effectiveness of the three drain spacings and were compared with SEW_{30} values from a nondrained area. Average annual SEW_{30} values were 72, 124, 242, and 648 cm-d for the 14-, 28-, 42-m, and nondrained areas, respectively. Differences in average annual SEW_{30} values among the four treatments were significant at the 5% significance level. Significant decreases in yield due to high water tables did not occur until annual SEW_{30} values exceeded 242 cm-d.

Average sugar yields from the subsurface drained treatments were compared with those from the nondrained area to determine the response of sugarcane to drainage. Average annual sugar yields were 6041, 6029, 5788, and 4990 kg/ha for the 14-, 28-, 42-, and nondrained areas, respectively. Sugar yields did not differ significantly among the three drain spacings, but sugar yields from the drained treatments were greater (significant at the one percent level) than yields from the nondrained treatment. There was no significant sugar yield advantage to spacing subsurface drains closer than 42 m.

The cost of installing subsurface drainage systems with drains spaced 28 and 42 m was justified by the value of increased sugar yields due to subsurface drainage. Since no yield advantage exists for drains closer than 42 m, the recommended drain spacing for Jeanerette silty clay loam soil is 42 m.

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